A.D. 1860, *25th August.* N° 2047.

Telegraphic Communication.

LETTERS PATENT to William Thomson, Doctor of Laws, Professor of Natural Philosophy in the University and College of Glasgow, in the County of Lanark, and Fleeming Jenkin, of Stowting, in the County of Kent, Civil Engineer, for the Invention of "IMPROVEMENTS IN THE MEANS OF TELEGRAPHIC COMMUNICATION."

Sealed the 7th February 1861, and dated the 25th August 1860.

PROVISIONAL SPECIFICATION left by the said William Thompson and Fleeming Jenkin at the Office of the Commissioners of Patents, with their Petition, on the 25th August 1860.

We, WILLIAM THOMSON, Doctor of Laws, Professor of Natural Philosophy in the University and College of Glasgow, in the County of Lanark, and FLEEMING JENKIN, of Stowting, in the County of Kent, Civil Engineer, do hereby declare the nature of the said Invention for "IMPROVEMENTS IN THE MEANS OF TELEGRAPHIC COMMUNICATION," to be as follows:—

We provide means by which signals are sent through telegraph wires with great speed and regularity, and we adjust the various contacts between the line and the source of electricity so as to obtain an increase in the speed of signalling through submarine and underground wires. We also employ instruments by which each signal prints or shows a symbol or letter, by means herein-after described.

All electric signals sent through conducting wires cause a continuous change

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in the strength of the electric current passing through each portion of the conducting wire. We employ those signals, in which during each signal that change occurs, in two opposite directions, and which are distinguished one from another by the length of time during which the current at the receiving end remains above or below a given strength, or by the difference between a given strength and the strength of current attained at the receiving end during each signal, or by the different direction in which the change from a given strength occurs. We adjust the contacts used to send these signals through submarine or underground lines in such a manner, that the final strength caused by each signal at the receiving end of the conducting wire shall be constant, or nearly constant; and we also provide that during the interval of time separating successive letters, words, or sentences, the current passing through the receiving end of the wire shall remain at the same constant strength. In suspended land wires, or other wires free from much inductive embarrassment, no special means are required for the purpose of maintaining the received current at a constant final strength; in such wires we do not use the peculiar contacts required by submarine or underground wires, but provide means by which signals can be sent with great speed and regularity.

We effect the desired objects by several means, and for the sake of clearness have divided the description of our improvements into seventeen parts.

First, we make signals through submarine or underground wires by varying the duration of the contacts between the wire and the source of electricity at the transmitting end; each signal is produced by two contacts, which we call the first and second contacts; by means of these contacts the line is successively put in connection with two sources of electricity of different potentials. One method of doing this is to arrange either one battery or two batteries so that they shall produce at the transmitting end positive and negative potentials, equal or unequal during the two contacts respectively. We regulate the relative length of the first and second contacts, so that the final strength of current at the receiving end of the wire is constant, that is to say, is the same, or nearly the same after each signal. To effect this the duration of the second contact is made nearly equal to that of the first. Thus, when Morse signals are used, the first and second contacts used in sending a dot are made equal, and the first and second contacts used in sending a dash are made nearly equal; the second contact should be made a little the shorter.

Second, during the time separating any two letters we maintain the current of the receiving end of the line at the constant final strength by one or more pairs of contacts, each about half the length of those required to make the

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shortest legible signal, such as the dot in the Morse alphabet. The two contacts used for this purpose are made nearly equal, but the second contact should be made a little the longer. These pairs of short contacts are continued during the pause separating any two letters, words, or sentences. We call these short contacts "space contacts."

Third, instead of using the pairs of space contacts we connect the transmitting end of the line during the pause separating any two letters, words, or sentences with a third source of electricity at a potential intermediate between those potentials used in connection with the first and second contacts; this third potential is calculated so as to maintain the constant final strength of current in the same manner as is done by the use of space contacts. The methods described do not alone apply to Morse signals, but, on the contrary, may be applied with advantage to any signals which depend on the length of time during which the conducting wire is connected with a source of electricity, and the beneficial effect of this method is not limited by precise proportions between the first and second contacts, on the contrary, whenever the length of the second contact is made somewhat longer after a long first contact than after a short first contact a beneficial effect will be produced.

Fourth, we employ signals which are distinguished one from another by the direction in which the change of the received current from a given strength occurs. On land wires this given strength is usually zero, and the two signals employed are called positive and negative signals respectively. In sending these signals through submarine or underground wires we employ two sources of electricity at different potentials, and the following sequence of contacts. For the positive signal we make one pair of contacts, the first contact being made with the source of electricity at the higher potential, and the second contact with the source of electricity at the lower potential, and we make the first contact the longer of the two. For the negative signal the order of the two contacts is reversed, and that contact which is now the first made the longer of the two. During the pause between successive words, letters, or sentences, pairs of space contacts of equal length are sent, as in our "second" improvement; or during the pause between successive letters, words, or sentences, we make contact between the line and a third source of electricity at a potential intermediate between the two other potentials, as in our "third" improvement. One of these three sources of electricity may be the earth.

Fifth, the methods described can be applied to the greatest advantage by a mechanical sender; for this purpose we use a rotatory key. By this key the contacts are made of the desired length when stops are simply touched in succession by the sending clerk. This key is constructed as follows:—Part of

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the mechanism revolves at an uniform speed, whilst other portions can be thrown into gear at will with the revolving system, and will continue to revolve for a definite time, making the contacts required for the signal which corresponds to the portion thrown into gear. The length of these contacts does not depend on the time during which the finger-pieces or stops which throw any portion into gear are pressed by the clerk, but on the speed of the revolving system, and on the shape of the parts used to make contact. The above key may be usefully employed on land lines where the "first," "second," "third," and "fourth" improvements are not required.

Sixth, our "first," "second," "third," "fourth," and "fifth" improvements are also applicable in submarine or underground lines to those signals which are distinguished one from another by the amount of variation of the received current from a given strength. The varied duration of contacts at the transmitting end not only causes a change in the length of time during which the received current remains above or below a given strength, but also changes the amount of variation from a given strength during that time. A prolonged contact between the line and a source of electricity causes a greater variation in the strength of the received current from what we have called the constant final strength than is caused by a contact of short duration. The sequence of contacts and sending mechanism described as our "first," "second," "third," "fourth," and "fifth" improvements may, therefore, be used to produce those signals which are distinguished by the amount of variation of the received current.

Seventh, for submarine or underground lines we also employ for the purpose of obtaining a constant final strength of current at the receiving end after each signal the method of signalling described as the fourteenth part of William Thompson's improvements in testing and working electric telegraphs, in his Patent bearing date of Twentieth February, One thousand eight hundred and fifty-eight, and part of our Invention consists in improved mechanism for the purpose of making Morse and other signals by this method.

The method alluded to is described in the Specification to the said Patent in the following words:—"When the wire is unelectrified to begin with, then "I apply, first, a stronger electro-motive force than that required to maintain the "current at the stated strength for a short time, and after that I apply the electro-"motive force just required to maintain a current at the stated strength, and "continue such application until the time comes to make the next signal; I "next apply for a short time an electro-motive force differing from the last by a "greater amount than that by which the electro-motive force corresponding to "the new signal differs from it, after which the electro-motive force simply

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" required to maintain the stated strength corresponding to the new signal is " applied and held on until it is time to commence a third signal, and so on." A pair of signals such as are here described require four distinct contacts We propose to use such a system of contacts for Morse or similar signals, which depend on the length of time for which the strength of the received current remains superior or inferior to a given strength, and also for those signals which are distinguished one from another by the direction in which the change of the received current from a given stated strength occurs. In the Morse signals the first "stated strength" will be the strength required to indicate a dot or dash, and the second "stated strength" the constant final strength, separating any two Morse signals. One dot or dash will therefore require four distinct contacts. In a dot, however, the second contact, or that required to maintain the current at the stated strength, may be infinitely short, and when no pause separates successive symbols, the fourth contact may also be infinitely short. The second contact, therefore, may be looked upon as necessary for the dash only, and the fourth contact for the pause between two consecutive letters, words, or sentences. We employ the same system for those signals which are distinguished one from another by the direction in which the change of the received current occurs.

The sequence of contacts then required is as follows:—The connections are arranged so that five sources of electricity at different potentials can be connected with the line; these will be called for clearness 1, 2, 3, 4, and 5, Number 1 being the source at the highest potential, and each successive number indicating a lower potential. For the positive signal the sequence of contacts is as follows:—First contact No. 1, second contact No. 4, third contact No. 3. For the negative signal the sequence of contacts is as follows:—First contact No. 5, second contact No. 2, third contact No. 3. When a pause is required between two letters, words, or sentences, the contact No. 3 is prolonged; when no pause is required it may be infinitely short, or in other words, may be omitted.

We use an improved key for the purpose of making the contacts described, which contains a main shaft revolving at uniform velocity; loose upon this shaft are certain arms or levers, which, by friction, are made to revolve at the same speed as the main shaft. These levers, by tappets and tumblers, make the four contacts required for Morse or similar signals in the order described. Stops under the control of the clerk arrest the arms at will, either during the second or fourth contacts, which are otherwise of very short duration. When dots are sent the revolving levers are not stopped. When dashes are sent the stop is pressed, by which the arms are arrested during the second contact.

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When a pause is required the stop is pressed, which arrests the arms duringh the fourth contact. A dash or pause is thus made corresponding in length to the time during which the arms have been stopped at the second or fourth contact respectively. A single stop may be so arranged as to produce the first stoppage when down, and the second when up may therefore be worked by the ordinary manipulation for Morse sending. We use the same key to make the five contacts required (as described above) for those signals which are distinguished one from another by the direction in which the change of the received current occurs. The contact called the second contact in the key, as adapted to Morse signals, must then be omitted, and an addition made to the mechanism by which the two batteries which supply the first and third contacts are reversed at each change of sign in the signal.

Eighth, we also make the sequence of contacts required to carry out our "first," "second," "third," "fourth," and "sixth" improvements by preparing the message in paper or by type, which passing through suitable mechanical arrangements at a regulated speed, make the required contacts. We prefer using embossed paper for this purpose. The general appearance of the paper is similar to that of the ordinary Morse receiving paper. The strip of prepared paper is drawn by rollers at a uniform speed past suitable levers, by means of which the embossed parts of the paper make contact between the line and a source of electricity by pressing a moveable contact tongue against a fixed contact piece. The length of the boss determines the length of the contact. The position of the boss transversely on the paper may determine the nature of the contact, two or more contact makers being employed side by side, each of which is moved by the bosses of only one of the parallel rows, and puts the line in connection with a separate source of electricity. We also use the spaces, separating the bosses longitudinally, to make contact. The contact tongue is pressed against one contact piece by the boss, and brought back against a second contact piece by a spring when the boss has passed. Thus, one contact maker may put the line in connection with two sources of electricity successively, and two contact makers will be sufficient to connect the line with four sources of electricity successively.

Ninth, the paper is stamped with bosses of the required lengths by means of an embossing key. In this key, as adapted to Morse signals sent by the sequence of contacts described in our "first" and "second" improvements, there are three stamps of the three lengths required for the dot, dash, and space contacts; any one of these stamps may be impressed by means of a suitable finger piece on the paper, which remains fixed to receive the impression. The rise of the stamp, after making the impression, causes the forward

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motion of the paper by means of drawing rollers moved by a ratchet wheel and pauls. The amount of rise either directly, or by the interposition of different levers for the different bosses, determines the distance to which the paper is drawn forward after each impression or boss is made. With slight modification the same key can be used to impress bosses suited to any required sequence of contacts.

Our "eighth" and "ninth" improvements may be used with advantage to make the sequence of contacts required for any of the usual methods of signalling, and especially to make the sequence of contacts required to carry out the fourteenth part of William Thomson's Patent, bearing date Twentieth February, One thousand eight hundred and fifty-eight, already quoted.

Tenth, we employ instruments by which each mechanical signal (such as the depression of a stop) prints or shows a symbol or letter; for this purpose we employ a sending arm and a receiving disc or type wheel driven by friction at equal speeds. When the sending arm is arrested by a stop the contacts between the sending battery and the line are so modified that the receiving disc or type wheel is stopped by the action of an electro-magnetic detent, when the arm is allowed to resume its motion the original contacts are re-established, and the receiving disc or type wheel being released also resumes its motion. The angular motion of the sending arm between two successive stoppages and that of the receiving disc or type wheel are consequently equal if stops corresponding to an alphabet are ranged round the sending arm, and corresponding letters or types fixed to the receiving disc or type wheel the angular motion of the sending arm which occurs when stop "A" is released, and stop "G" depressed will allow an equal angular motion in the receiving disc or type wheel, and thus that disc or type wheel (previously set with "A" visible, or opposite the printing roller) will be stopped with "G" in sight or opposite the printing roller; during the stoppage, the letter is read or printed by a local circuit, or by a mechanical arrangement. If the stop "E" is next depressed at the sending station, and the stop "G" released, the letter "E" will also be read or printed at the receiving station, and thus any succession of symbols may be transmitted. When the instrument is required only to show letters, not to print them, an arm attached to the receiving wheel may be used to point to letters on a fixed dial behind it. The time during which the sending arm is stopped is immaterial, provided it is stopped for sufficient time to allow of the contacts being made at the sending end, and the letter read or printed at the receiving end. A single instrument answers the purpose of transmission and reception, the sending arm being fastened to the receiving disc; when sending, it is arrested by the stops; when receiving, it is stopped by

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the electro-magnetic detent. When this instrument is constructed for use on submarine or underground lines, the stoppage of the arm causes the two contacts described in our "seventh" improvement as the first and second contacts to take place, the second contact being prolonged until the arm is released, the restored motion of the arm causes what were called the third and fourth contacts to take place, the fourth contact being prolonged until the arm is again stopped, these four contacts being required to carry out the fourteenth part of William Thomson's Patent, dated Twentieth February One thousand eight hundred and fifty-eight.

Eleventh, we use an electro-magnetic detent made as follows:—A bar of soft iron is supported inside two galvanometric coils, so as to be free to move back and forwards along their axis between two stops. The two coils are fixed with their axes in line; they are so connected that the current passes through them in opposite directions round their common axis. The bar of soft iron is powerfully magnetized by a large horse-shoe magnet, the two poles of which are placed opposite the ends of the soft iron bar, the received current passing through the two galvanometric coils causes each to exert a force on the magnetized bar of soft iron, tending to move it in the same direction along the axis. This force is used to move the bar from one stop to the other; the cessation or reversal of the current causes the return of the bar to its original position. The strength of current in the coils by which the movement of the soft iron bar is determined from one stop to the other can be adjusted either by a spring or by a magnetic adjustment. We use the same combination of coils, soft iron, and magnet as a "relay" or "pecker," the movement of the bar of soft iron under the influence of a current being used to make and break contact.

Twelfth, we regulate the motion of those parts of our mechanism which revolve at an uniform speed by a governor which applies a break. One form of governor employed is called by us the "static reaction governor." This governor is a centrifugal governor, in which the static reaction resisting the centrifugal force developed in the revolving mass is employed to apply a break to the revolving shaft, of which the motion is to be controlled, whilst at the same time this application of the reaction is so contrived as not to affect the divergence of the revolving mass from the axial shaft. We employ two forms of this governor. In the first form the axial revolving shaft is vertical, and a single ball or mass of any convenient shape carried by an arm hinged on the axial shaft is employed. The axial shaft is in the prolongation of the driving shaft, but is hinged on this shaft so as to be free to deflect from its vertical position. This deflection is restrained within a very small limit by an horizontal arm

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projecting from the axial shaft, the other end of which presses against a fixed surface of revolution, and produces the required friction. The divergence of the ball or mass from the axis of the shaft is not affected by the use made of the tension of the arm to apply the break. In the second form of governor, a spring is substituted for the action of gravity to restrain the centrifugal force of the revolving mass or masses. The static reaction of this spring sliding on a fixed surface, which is either a plane surface perpendicular to the shaft, or a coaxial surface of revolution, produces the required friction. The spring is so adjusted as to exert a force in simple proportion to the angle of displacement for small displacements, and there is no great deviation from this law throughout the entire range of displacement. The divergence of the rotating mass from the axial shaft is not affected by the employment of the reaction of the spring to produce friction, or, in other words, to apply the break. In both forms the movement of the mass is limited by stops which permit it to move from a point very near that of unstable equilibrium (so far as centrifugal force is concerned) through an acute angle towards the position of stable equilibrium (so far as centrifugal force is concerned.) Until the required speed is attained, the mass presses towards the axial shaft against the inner stop, but when the required speed is passed even by a very small quantity, the mass diverges considerably from the axis, and by the above arrangements, can be made to exert a large break power.

Thirteenth. Another governor used by us is called the spring and pallet governor. We use the usual form of single or double ball governor so far as the general features of the revolving system are concerned. A catch projects from one or both balls outward from the central shaft. When the divergence of the ball or balls exceeds a certain limit this catch comes in contact with a series of fixed springs arranged in a circle round the axis of the governor. These springs are so fixed and shaped, that by a small displacement of the end struck the catch and ball are allowed to pass. The surface of contact of the spring and catch must form nearly the limiting angle of friction with the normal to the circular line of motion of the catch in order that no force may be exerted by the springs either to press the catch towards the axis, or to retain it at a distance from the axis. The retarding force is that which is exerted by the springs to prevent the passage of the ball and catch. This form may be varied by placing a spring on the ball and catches in a circle round the axis of the governor.

Fourteenth, we also use a chronometric governor where great accuracy is required. In this governor break power used to prevent the mechanism from passing a certain speed is increased or diminished respectively during any

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deviation of a mass from the axis round which it rotates greater or less than one constant deviation. So long as the speed required is accurately kept, the mass revolves unimpeded at a constant distance from the axis, and the retarding force is unaltered. Any increase of speed by increasing the distance of the mass from the axis brings the mass into contact with a catch or tooth on a wheel, which being turned by the mass, as it revolves increases the break power, until the speed is reduced to that required; any diminution of speed, by diminishing the distance of the mass from its axis, brings the mass into contact with a catch or tooth on a second wheel, which being turned by the mass, as it revolves, diminishes the break power until the speed is increased to that required.

Fifteenth. It is of great importance that there should be little variation in the electro-motive force or resistance of the batteries employed; we therefore use Daniell's constant batteries of the following forms:—When porous cells are employed to separate the two liquids we connect the two liquids by means of a syphon, and thus prevent any change of relative level in the surface of the two liquids.

Sixteenth. We also use a portable Daniell's battery without porous cells. A trough or saucer is made of insulating material; a piece of copper or other positive metal is bolted to the bottom by a bolt passing through the bottom of the trough or saucer. The opening is made water-tight by the use of an elastic washer under the head of the bolt; powdered crystals of sulphate of copper are strewn on the plate; a layer of sawdust is next placed in the saucer moistened with sulphuric acid and water. On the top of the sawdust, nearly level with the top of the saucer, a zinc plate is laid; several of these saucers having been thus prepared, they are laid one on the top of the other; the bolts passing through the bottom of each saucer form directly or indirectly the connexion required between each cell. The saucers are then firmly secured together by bolts passing through lugs on the saucers, or by other suitable means.

Seventeenth. We use an instrument which we call a "divider." By this instrument a difference of potentials is produced in two terminals equal to any definite part of the difference of potentials resulting from one or more cells, and thus currents of various definite strengths are produced in any arc joining the two terminals. We use this instrument to subdivide electro-motive force in working our "seventh" improvement in balancing earth currents, and in many other combinations.

The instrument is constructed as follows:—The two poles of the cell or battery are connected through a reversing key with a series of "n" equal.

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resistance coils; the end of each coil is connected with the beginning of the next at a brass terminal; there are thus "$n+1$" terminals. These terminals are arranged in a row, and numbered 0, 1, 2, 3 . . . . n. A stout brass bar is fixed parallel to the row of terminals, and a spring slides on the bar so that it can readily be brought by hand to press on any one of the terminals; when the spring is at terminal 0, that terminal and the bar are simply put in short metallic communication so as to be maintained at the same potential. When the sliding piece is drawn along the bar so as to make the spring press on any other terminal, No. 1, for instance, the bar and the terminal 0, if kept perfectly insulated from earth and also from one another except through the spring and resistance coil, are maintained at a difference of potential amounting to the fraction $\frac{1}{n}$ of the whole difference of potential maintained by the battery at the extreme terminals "0" and "$n+1$." By the use of the reversing key this difference of potentials may be reversed.

If the bar and the terminal 0 are now joined by an arc of which the resistance is great compared with that of the resistance coils, the difference of potentials in the bar and the terminal 0 will still be that called $\frac{1}{n}$, and a current will flow through the arc. If this current be called "a," then the current flowing through the arc when the spring is at terminal 2 will be $2a$, the difference of potentials in the bar and the terminal 0 being then $\frac{2}{n}$, and generally when the spring is at terminal "m," a current will flow through the arc equal to "ma," the difference of potentials in the bar and the terminal 0 being then equal to $\frac{m}{n}$.

When the additional arc joining the bar and the terminal 0 is of small resistance compared with that of the resistance coils the relation of the various currents produced in the arc when the spring is at different terminals is no longer so simple, but these currents may be calculated, if desired, according to established principles, from the resistance of the battery, and of the several arcs dealt with.

SPECIFICATION in pursuance of the conditions of the Letters Patent, filed by the said William Thomson and Fleeming Jenkin in the Great Seal Patent Office on the 25th February 1861.

TO ALL TO WHOM THESE PRESENTS SHALL COME, we, WILLIAM THOMSON, Doctor of Laws, Professor of Natural Philosophy in the University and College of Glasgow, in the County of Lanark, and FLEEMING JENKIN, of Stowting, in the County of Kent, Civil Engineer, send greeting.

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Thomson & Jenkin's Improvements in the Means of Telegraphic Communication.

WHEREAS Her most Excellent Majesty Queen Victoria, by Her Letters Patent, bearing date the Twenty-fifth day of August, in the year of our Lord One thousand eight hundred and sixty, in the twenty-fourth year of Her reign, did, for Herself, Her heirs and successors, give and grant unto us, the said William Thomson and Fleeming Jenkin, Her special licence that we, the said William Thomson and Fleeming Jenkin, our executors, administrators, and assigns, or such others as we, the said William Thomson and Fleeming Jenkin, our executors, administrators, and assigns, should at any time agree with, and no others, from time to time and at all times thereafter during the term therein expressed, should and lawfully might make, use, exercise, and vend, within the United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, an Invention for "IMPROVEMENTS IN THE MEANS OF TELEGRAPHIC COMMUNICATION," upon the condition (amongst others) that we, the said William Thomson and Fleeming Jenkin, our executors or administrators, by an instrument in writing under our, or their, or one of our or their hands and seals, should particularly describe and ascertain the nature of the said Invention, and in what manner the same was to be performed, and cause the same to be filed in the Great Seal Patent Office within six calendar months next and immediately after the date of the said Letters Patent.

NOW KNOW YE, that we, the said William Thomson and Fleeming Jenkin, do hereby declare the nature of our said Invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement (that is to say):—

We provide means by which signals are sent through telegraph wires with great speed and regularity, and we adjust the various contacts between the line and the sources of electricity so as to obtain an increase in the speed of signalling through submarine and underground wires. We also employ instruments by which each signal prints or shows a symbol or letter by means herein-after described. All electric signals sent through conducting wires cause a continuous change in the strength of the electric current passing through each portion of the conducting wire. We employ those signals in which during each signal that change occurs in two opposite directions, and which are distinguished one from another by the length of time during which the current at the receiving end remains above or below a given strength; or by the difference between a given strength and the strength of current attained at the receiving end during each signal, or by the different direction in which the change from a given strength occurs.

Figures 1, 2 and 3, represent graphically the nature of the change of

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strength in the received current, produced by these three kinds of signals. The ordinates to the curves represent the strength of the current; the abscissæ represent the intervals of time which separate the several strengths one from another. We adjust the contacts used to send these signals through submarine or underground lines, in such a manner that the final strength caused by each signal at the receiving end of the conducting wire shall be constant or nearly constant, and we also provide that during the interval of time separating successive letters, words, or sentences, the current passing through the receiving end of the wire shall remain at the same constant strength. Thus the curves representing the change in the received current during signals sent by our mechanism will appear as shown in Figures 1, 2 and 3, instead of resembling the more irregular curves shown in Figures 4, 5 and 6, which represent the nature of the changes produced by common hand signalling, even when perfect time is kept. In suspended land wires, or other wires free from much inductive embarrassment, no special means are required for the purpose of maintaining the received current at a constant final strength. In such wires we do not use the peculiar contacts required for submarine or underground wires, but provide means by which signals can be sent with great speed and regularity. We effect the desired objects by several means, and for the sake of clearness have divided the description of our improvements into seventeen parts.

First, we make signals through submarine or underground wires, by varying the duration of the contacts between the wire and the sources of electricity at the transmitting end; each signal is produced by two contacts which we call the first and second contacts; by means of these contacts, the line is successively put in connection with two sources of electricity, of different potentials; one method of doing this is to arrange either one battery, or two battaries, so that they shall produce at the transmitting end positive and negative potentials, equal or unequal, during the two contacts respectively. We generally, however, use the earth at the sending station as one of the sources of electricity. We regulate the relative length of the first and second contacts so that the final strength of current at the receiving end of the wire is constant, that is to say, is the same or nearly the same, after each signal. To effect this the duration of the second contact is made nearly equal to that of the first; thus, when "Morse signals" are employed, the first and second contacts used in sending a "dot," are made equal, and the first and second contacts used in sending a "dash," are made nearly equal; the second contact should be made a little the shorter.

Second, during the time for separating any two letters, we maintain the current at the receiving end of the line at the constant final strength by one

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or more pairs of contacts, each about half the length of those required to make the shortest legible signal, such as the dot in the Morse alphabet. The two contacts used for this purpose are made nearly equal, but the second contact should be made a little the longer. These pairs of short contacts are continued during the pause separating any two letters, words, or sentences. We call these short contacts "space contacts."

Figure 7 represents the series of contacts required to send the words "id est" in Morse signals, by our first and second improvements. The length of the black lines represents the duration of the first contacts. The length of the blank spaces separating the black lines represents the duration of the second contacts required. The contacts shown are three pair of space contacts, two dots, one pair of space contacts, one dash, two dots, &c. The signals sent by these contacts will appear at the receiving end, as shown in Figure 2.

Third, instead of using the pairs of space contacts we connect the transmitting end of the line during the pause separating any two letters, words, or sentences with a third source of electricity, at a potential intermediate between those potentials used in connection with the first and second contacts. This third potential is calculated so as to maintain the constant final strength of current in the same manner as is done by the use of space contacts.

Figure 8 represents the contacts required to send the words "id est" by Morse signals, using our first and third improvements. The thick black lines and blank spaces represent first and second contacts, as before. The thin black lines represent contacts with the third source of electricity at a potential intermediate between the two potentials used for the first and second contacts. The signals sent by these contacts will appear at the receiving end, as shown in Figure 2. The methods described do not alone apply to "Morse signals," but, on the contrary, may be applied with advantage to any signals which depend on the length of time during which the conducting wire is connected with a source of electricity, and the beneficial effect of this method is not limited by precise proportions between the first and second contacts; on the contrary, whenever the length of the second contact is made somewhat longer after a long first contact than after a short first contact, a beneficial effect will be produced.

Fourth, we employ signals which are distinguished one from another by the direction in which the change of the received current from a given strength occurs, as represented in Figure 3. On land wires this given strength is usually zero, and the two signals employed are called positive and negative signals respectively. In sending these signals through submarine or underground wires, we employ two sources of electricity at different potentials, and

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the following sequence of contacts:—For the positive signal we make one pair of contacts, the first contact being made with the source of electricity at the higher potential, and the second contact with the source of electricity at the lower potential, and we make the first contact the longer of the two. For the negative signal the order of the two contacts is reversed, and that contact which is now the first is made the longer of the two. During the pause between successive words, letters, or sentences, pairs of space contacts of equal length are sent as in our "second" improvement; or, during the pause between successive letters, words, or sentences, we make contact between the line and a third source of electricity at a potential intermediate between the two other potentials, as in our "third" improvement. One of these three sources of electricity may be the earth. The broken line in Figures 9 and 10 represents the sequence of contacts required to send the words "id est" in positive and negative signals by our "fourth" and "second," or by our "fourth" and "third" improvements respectively. The ordinates represent the potentials of the different sources of electricity. The abscissæ represent the lengths of time during which they are connected with the line. The signals sent by these contacts will appear at the receiving end, as shown in Figure 3. These signals, although they may be called positive and negative relatively to each other, are not necessarily positive or negative relatively to the earth's potential.

Fifth, the methods described can be applied to the greatest advantange by a mechanical sender; for this purpose we prefer to use a rotatory key. By this key the contacts are made of the desired length, when stops are simply touched in succession by the sending clerk. This key is constructed as follows:—Part of the mechanism revolves at an uniform speed, whilst other portions can be thrown into gear at will with the revolving system, and will continue to revolve for a definite time making the contacts required for the signal, which corresponds to the portion thrown into gear. The length of these contacts does not depend on the time during which the finger pieces or stops which throw any portion into gear are pressed by the clerk, but on the speed of the revolving system, and on the shape of the parts used to make contact. This key is shewn in Figures 11 to 11°. Figure 11 gives a general plan, front elevation and side elevation. The remaining Figures shew details. The parts and action are as follows:—A, dot stop hinged at *f*; B, space stop hinged at *g*; C, dash stop hinged at *h*; "*a*, *b*, *c*," bent levers, which prevent more than one stop being down at once; E, G, springs pressing up stops A and C; F, spring pressing down stop B; *f*, *g*, *h*, shafts transmitting the movement of the three finger stops to the three forks H, I, K; R, S, two plain discs

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fast on shaft *k*, *k*; T a plain disc fast on shaft *i*, *i*; V, V, shaft driven by clock-work at a uniform speed, and giving motion by gearing to shafts *k*, *k*, and *i*, *i*; the shaft *k*, *k*, makes two revolutions, whilst *i*, *i*, makes one; L, L, N, N, arms loose on shafts *k*, *k*, *i*, *i*, respectively. These arms are alike, and are shewn in detail in Figure 11^{b}. They are made to traverse a short distance along the shaft by the forks H and K, which hold a loose collar λ (Figure 11^{b}); M, M, quadruple arms, shewn in detail in Figure 11^{c}. They can be moved back and forwards along shaft *k*, *k*, by the fork I; O, P, Q, three bearings, having each a fixed clutch δ (Figure 11^{b}) on one face.

When any of the sets of arms L, L, M, M, or N, N, are out of gear with their clutch, they revolve at the speed of the discs R, S, & T, respectively being driven by the friction of the projecting adjustable pieces θ (Figure 11^{b} and Figure 11^{c}) which are pressed against the large discs R, S and T, by the surface of the clutch. *m*, *n*, m^{1}, n^{1}, m^{11}, n^{11}, are three sets of tappets, one of which is shewn in detail in Figure 11^{a}. These tappets are all on one shaft *p*, *q*, at the end of which fast on it is the tongue or tumbler *r*. This tumbler, as shewn, consists of a tongue of soft iron, oscillating between two poles of a horse-shoe magnet, on which are the two terminals *t* and *s*; *r* is in connection with the line; *t* and *s* with the two sources of electricity, other forms of tumbler may be used. The end α of the arms L, L, when they begin to revolve, strikes the screw *n*, and throws *r* into contact with *t* where it remains, making the "first contact" till the end β striking *m* throws *r* back against *s*, and makes the "second contact." When the arms are still (being in gear with the clutch) they are clear of the tappets, but α is just ready to strike *n*. The arms N, N, act in like manner by means of tappets m^{11}, n^{11}. The arms M, M, strike the tappets m^{1}, n^{1}, and the tumbler *r* back and forwards twice during each revolution. When the stops A and C are up, the forks H and K press the arms L, L, and N, N, into clutches δ (Figure 11^{b}) on the bearings O and Q; in this position the arms cannot revolve. The stop B will then (in consequence of the levers *a*, *b* and *c*) be down, and the fork I will press the arms M, M, out of gear with the clutch on P when they will revolve at the speed of the disc S making continuously pairs of space contacts by striking the tappets m^{1}, n^{1}. If the stop A be now pressed, it will not go down until the arms M, M, come into such a position that they can enter the clutch at P, into which they will be thrown by the action of the lever *a* lifting B and moving fork I. When this occurs A will go down, the arms M, M, will stop, and the arms L, L, will begin to revolve. If the pressure be then withdrawn from A that stop will not rise until the clutch at O allows the arms L, L, to fly back from the disc R, having made an entire revolution and completed

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the two dot contracts by striking *n* and *m*. A will then rise, B will fall, and the arms M, M, again begin to send space contacts. The same description applies to C and N, N, but the time occupied by a revolution of L, L, or M, M, will be two-thirds of that taken by N, N. Thus, only one of these three sets of arms can revolve at once, and the movement of each set can only begin and end at certain definite periods of time. When the clerk is not sending, arms M, M, revolve continuously, making two pairs of space contacts during each revolution. When a dot is to be sent, he presses A, which will presently yield to the touch; M, M, will then stop, and L, L, will complete the two dot contacts. If then no stop is pressed down L, L, will stop, and space contacts will begin again; but if meanwhile the clerk has begun to press C or continues to pass A, the contacts for a dash or for another dot will be made. The length of the pairs of contacts depends on the speed of the shafts *k*, *k*, and *i*, *i*. The relative lengths of the "1st and 2nd contacts" depend on the position of the ends α and β, of the several arms. φ, φ, are pieces, which permit an adjustment of the relative position of the ends α and β. The above key may be usefully employed on land lines where the "first," "second," "third," and "fourth" improvements are not required.

Sixth, our "first," "second," "third," and "fifth" improvements are also applicable in submarine or underground lines to those signals, which are distinguished one from another by the amount of variation of the received current from a given strength, as may be seen on examination of Figure 2, which represents the varying strength of the received current due to Morse signals sent by our "first" and "second" improvements, or "first" and "third," improvements. The varied duration of contacts at the transmitting end not only causes a change in the length of time during which the received current remains above or below a given strength, but also changes the amount of variation from a given strength during that time. A prolonged contact between the line and a source of electricity causes a greater variation in the strength of the received current, from what we have called the constant final strength than is caused by a contact of short duration. The sequence of contacts and sending mechanism described, as our "first," "second," "third," and "fifth" improvements may therefore be used to produce those signals, which are distinguished by the amount of variation of the received current.

Seventh, for submarine or underground lines we also employ for the purpose of obtaining a constant final strength of current at the receiving end after each signal the method of signalling described as the fourteenth part of William Thomson's "Improvements in Testing and Working Electric Telegraphs," in his Patent bearing date the 20th February 1858, and part of

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our Invention consists in improved mechanism for the purpose of making Morse and other signals by this method.

The method alluded to is described in the Specification to the said Patent in the following words:—"When the wire is unelectrified to begin with, then "I apply first a stronger electro-motive force than that required to maintain "the current at the stated strength for a short time, and after that I apply "the electro-motive force just required to maintain a current at the stated "strength, and continue such application until the time comes to make the "next signal; I next apply for a short time an electro-motive force, differing "from the last by a greater amount than that by which the electro-motive "force corresponding to the new signal differs from it, after which the electro-"motive force simply required to maintain the stated strength corresponding "to the new signal is applied, and held on until it is time to commence a third "signal, and so on." A pair of signals, such as are herein described, require four distinct contacts. We propose to use this system of contacts for Morse or similar signals, which depend on the length of time for which the strength of the received current remains superior or inferior to a given strength; and also for those signals which are distinguished one from another by the direction in which the change of the received current from a given stated strength occurs. In the Morse signals the first "stated strength" will be the strength required to indicate a dot or dash, and the second "stated strength," the constant final strength separating any two Morse signals. One dot or dash will therefore require four distinct contacts. In a dot, however, the second contact, or that required to maintain the current at the "stated strength" may be infinitely short, and when no pause separates successive symbols the fourth contact may also be infinitely short. The second contact therefore may be looked upon as necessary for the dash only, and the fourth contact for the pause between two consecutive letters, words, or sentences. The contacts required to send the words "id est" upon this system are represented in Figure 12, in which the ordinates and abscissæ have the same signification as in Figures 9 and 10.

One arrangement of the connections required to make these contacts is shewn in Figure 14[a]; L and E are two terminals, in connection respectively with the line and with earth; 1, 2, 3, 4, are four terminals connected, as shown in the diagram; C, Z, being the copper and zinc poles of a battery, and Y, a terminal, in connection with one of the wires joining a pair of plates near the copper pole of the battery; E^1 is the earth at the sending station; *e* is the earth at the receiving station; L^1 is the line. To send signals by the sequence of contacts described L must first be connected with 1, and E with 4,

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for a definite time; this connection sends a positive current through the line, with the whole electro-motive force of the battery; E must next be removed from 4 and connected with 2; as long as this connection is maintained a positive current is sent through the line from part C, Y, of the battery; L is next connected with 3, and a negative current is thus sent through the line by the part Y, Z, of the battery; lastly, E is connected with 4, and the line is thus connected with earth at both ends. When a dot is to be sent the connection between E and 2 is very short; when a dash is sent this connection is prolonged. When no pause is required between two signals the simultaneous connection between L and 3 and between E and 4 is very short, L being disconnected from 3 and connected to 1 immediately after the contact between E and 4 is made. During a pause between two signals both ends of the line remain in connection with the earth. The best subdivision of the battery, or in other words, the best position of Y, varies with varying circumstances: it can be readily adjusted in each case by experiment.

In this arrangement the four sources of electricity are as follows:—1st source, pole C of battery C, Z; 2nd source, pole C of battery C, Y; 3rd source, pole Z of battery Z, Y; 4th source, the earth; thus one source of electricity is at a potential lower than that of the earth, and sends a negative current. If desired, none but positive currents may be used; but then the line would not be put to earth during the fourth contact, but would transmit a weak positive current during that contact. Similarly, if desired, none but negative currents may be used, and then the line will transmit a weak negative current during the fourth contact. In other words, the four sources of electricity may be either all positive, all negative, or some positive and some negative; any one of them may be equal to zero. We employ the same system for those signals which are distinguished one from another by the direction in which the change of the received current occurs.

The sequence of contacts then required is as follows:—The connections are arranged so that five sources of electricity at different potentials can be connected with the line; these will be called, for clearness, 1, 2, 3, 4, and 5, No. 1 being the source at the highest potential, and each successive number indicating a lower potential. For the positive signal the sequence of contacts is as follows:—First contact No. 1; second contact No. 4; third contact No. 3. For the negative signal the sequence of contacts is as follows:—First contact No. 5; second contact No. 2; third contact No. 3. When a pause is required between two letters, words, or sentences the contact No. 3 is prolonged; when no pause is required it may be infinitely short, or in other words, may be omitted.

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The contacts required to send the words "id est" on this system are represented in Figure 13, in which the five sources of electricity are numbered according to their potentials.

One arrangement of connections adapted to send signals on this system is represented in Figure 14*f*, in which the terminals 1, 2, 3, 4, are connected with a battery in the same manner as in Figure 14*a*; the terminals L and E instead of being connected with the line, and earth directly are connected to two terminals of a commutator U by which either L is connected with the line and E with earth or E with the line, and L with the earth. When the commutator is in the former position positive dots or dashes might be sent by exactly the same sequence of contacts as that described for Figure 14*a*; but when the commutator is in the second position, as shewn in the diagram, negative dots or dashes will be sent by the same sequence of contacts.

The five sources of electricity above named are the folllowing.—"1," is the copper pole C of the battery, the zinc pole being connected with earth and Y insulated; "2" is the copper pole C, the terminal Y being connected with earth; "3" is the earth; "4" is the zinc pole of the battery, Y being put to earth; "5" is the zinc pole of the battery, C being put to earth.

Besides these five sources of electricity at five different potentials required for positive or negative dots there are two others, by which positive and negative dashes might be sent by the same sequence of contacts, prolonging the second contact.

We call these two other sources of electricity 2^a and 4^a. 2^a is C when the intermediate point Y is connected with earth, and Z insulated; 4^a is the intermediate point Y when the terminal C is connected with earth and Z insulated.

It should be remarked that although they may strictly be called positive and negative relatively to some neutral line which separates the two signals, signals of this kind are not necessarily positive and negative relatively to the potential of the earth. The five sources of electricity may if required all have higher potentials than that of the earth, or all lower potentials, so that only positive or only negative currents may be employed at will. Arrangements of batteries differing from that shown in Figure 14*f* are then necessary and can easily be made, the one essential point being that the relative potentials for the several contacts shall be such as have been described in the above instance.

We use an improved key for the purpose of making the contacts described, which contains a main shaft revolving at uniform velocity; loose upon this shaft are certain arms or levers, which by friction are made to revolve at the same speed as the main shaft.

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These levers by tappets and tumblers make the four contacts required for Morse or similar signals in the order described. Stops under the control of the clerk arrest the arms at will, either during the second or fourth contacts, which are otherwise of very short duration. When dots are sent the revolving levers are not stopt. When dashes are sent, the stop is pressed, by which the arms are arrested during the second contact. When a pause is required, the stop is pressed, which arrests the arms during the fourth contact. A dash or a pause is thus made corresponding in length to the time during which the arms have been stopped at the second or fourth contact respectively. A single stop may be so arranged as to produce the first stoppage when down, and the second when up, and may therefore be worked by the ordinary manipulation for Morse sending. A key so arranged is shown in Figure 14 *b*, *c*, *d*, and *e*; 14^b is a front elevation of the principal parts of the key; 14^c, a side elevation of some parts; 14^d, a plan of a portion of the key, and 14^e, a side elevation of a portion of the key; B, B, is a shaft driven at a uniform speed by clockwork, which is not shown; C is a smooth disc fast on shaft B, revolving in the direction shown by the arrow; D is a hollow shaft loose on shaft B, but driven at the same speed as shaft B by the friction of the spring F, F, against the disc C, unless stopped by other means. Besides the spring F, F, the hollow shaft carries two arms G, G, with tappets I and H. These tappets have inclined faces, by which, when the arm G, G, revolves, they move the tumblers O and P back and forwards in a direction at right angles to the plane of rotation of the arms. The tappets strike the inclined faces M and K on the tumblers P and O; these tumblers are hinged at L and E; M and K are insulated from P and O to prevent the tumblers from being put in connection with the brass work of the machinery when struck by I and H. L and E correspond to the terminals, which bear the same letters in Figures 14^a and 14^f; four springs 1, 2, 3, and 4, correspond to the four terminals, which bear the same ciphers in Figures 14^a and 14^f. These six parts are carefully insulated. The tumbler O can connect L and 1, or L and 3. The tumbler P can connect E and 2 or E and 4. A is a finger piece by which the shaft T, S, can be depressed; R is a spring, which lifts the shaft T, S, when the finger is removed; *a*, is a projection on the spring F, which comes against a projection *b* on the shaft T, S, when the shaft is in its highest position, and also against "*c*," a projection from a catch "*i*, *f*," hinged on the shaft T, S. This catch is pressed by a spring (not shewn) towards the shaft T, S. The key works as follows:—When no signals are being sent, the spring F, F, and consequently the arm G, G, are prevented from revolving by the stop "*a*" pressing against *b*. The friction of the revolving disc against F presses "*a*" also

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against the projection *c*, and thus keeps the catch *f* away from the shaft T, S, so that *f* does not catch on the surface *h*, and the descent of the shaft T, S, and of A is unopposed, except by the spring R. The tumbler O lies under spring 3 connecting L and 3, and is held firmly by the shape of the end of that spring. The tumbler P lies under spring 4, and connects E and 4. The line is thus put to earth (Figure 14[a]). There is on the shaft T, S, another projection *d*, the use of which will be presently explained.

To send a dot, A is depressed, the spring F is released by *b* and *c* descending below *a*, the spring F and arms G, G, begin to revolve at the speed of the shaft B, B, the tappet I at once moves the tumbler O from 3 to 1, and sends a positive current into the line; (Figure 14[a]) after making half a revolution the same tappet I moves tumbler P from 4 to 2, and cuts off part of the battery; if A continues depressed, *a* is stopped by *d*, and the contacts just made are prolonged; this sends a dash, the length of which depends on the time during which A is depressed. As soon as A is allowed to rise, *a* is freed from *d*, and the arms G, G, again begin to revolve, the tappet H moves the tumbler O from 1 back to 3, connecting L and 3, and sends a negative current through the line (14[a]). After half a revolution the same tappet H moves the tumbler P from 2 to 4, connecting the line with earth, and immediately afterwards the arms G, G, are arrested by the projection *a* catching on *b*. If the finger piece A had been allowed to rise immediately after being depressed, the simultaneous contact of L with 1, and E with 2, would have been of very short duration, and would have been immediately succeeded by the connection of L with 3 and E with 2. In this case, a dot instead of a dash would have been sent. As soon as A rises to its original position the catch *f* is drawn by a spring over the fixed surface *h* and prevents A from being again depressed before the arms G. G, have completed an entire revolution, or, in other words, until the projection *a* has again struck back the catch *f* into the position in which it is shown in the Drawing. As soon as this is the case the stop A can be again depressed. The manipulation is thus quite the same as that of an ordinary Morse key.

The length of the dot cannot, however, be made shorter than is due to the time occupied by one revolution of shaft B owing to the catch *f*. The length of the dash depends on the operator, who cannot, however, owing to the catch *f*, send another signal until the four contacts required are complete, or, in other words, until all the parts have resumed the position shown in the Drawing.

Figure 1 represents the varying strength of the received current due to those signals when the words "id est" are sent. We use the same key to make the five contacts required (as described above) for those signals which

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are distinguished one from another by the direction in which the change of the received current occurs. The contact called the second contact in the key, as adapted to Morse signals, may then be omitted, and an addition must be made to the mechanism by which the batteries which supply the first and third contacts are reversed at each change of sign in the signal. This is done in the following manner :—The finger piece A, instead of being directly moved by the finger, can be depressed by two stops, which we will call the right and left-hand stops. The depression of either stop starts the arm G, and the four contacts between the tumblers and terminals 1, 2, 3, and 4 are completed in exactly the same manner whichever of the two stops is used; but when the right-hand stop is used, a commutator connects L with L^1, and E with E^1; and the contacts are completed precisely as in the foregoing description of Morse signalling; whereas when the left-hand stop is used the commutator is reversed, and L^1 is connected with E, and E^1 with L (Figure 14*f*). By substituting the word negative for positive and positive for negative in the previous description of the contacts, the effect of using the left-hand stop will be accurately described.

Positive and negative dots only would generally be used, dashes being unnecessary. A touch on the right-hand stop would produce a positive dot, a touch on the left-hand stop a negative dot, the second contact being very short, and serving only to prevent mischief should the operator continue to depress either stop for an unnecessarily long time.

Eighth, we also make the sequence of contacts required to carry out our "first," "second," "third," "fourth," and "sixth" improvements, by preparing the message in paper, or by type, which passing through suitable mechanical arrangements at a regulated speed, make the required contacts. We prefer using embossed paper for this purpose. The general appearance of the paper is similar to that of the ordinary Morse receiving paper. The strip of prepared paper is drawn by rollers at a uniform speed past suitable levers, by means of which the embossed parts of the paper make contact between the line and a source of electricity by pressing a moveable contact tongue against a fixed contact piece. The length of the boss determines the length of the contact.

The position of the boss transversely on the paper may determine the nature of the contact, two or more contact makers being employed side by side, each of which is moved by the bosses of only one of the parallel rows, and puts the line in connection with a separate source of electricity. We also use the spaces separating the bosses longitudinally to make contact. The contact tongue is pressed against one contact piece by the boss and brought back against a second contact piece by a spring when the boss has passed. Thus, one contact maker

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may put the line in connection with two sources of electricity successively, and two contact makers will be sufficent to connect the line with four sources of electricity.

Figure 15 shows one manner in which the bosses make the contacts required for our first and second improvements. A drum A on the shaft B is driven at an uniform speed by clockwork. The paper is passed through a guiding staple E over the drum A and under a grooved friction roller C, which is pressed against A by the spring D. A flat broad spring F, armed at L with platinum, is raised or allowed to fall respectively, as a boss or intermediate space is under the projection G. When the space is under G, L presses, by the nutural elasticity of spring F, against the screw K armed with platinum. When a boss passes under G, it lifts F and presses L against the screw I armed with platinum. Now, if H is in connection with the line, I and K will make the first and second contacts required to send signals as the bosses are drawn under G at an uniform speed by the drum A. The screws I and K can be adjusted to suit the amount of motion given by the bosses on the paper.

Ninth, the paper is stamped with bosses of the required lengths by means of an embossing key. In this key, as adapted to Morse signals sent by the sequence of contacts described in our "first" and "second" improvements, there are three stamps of the three lengths required for the dot, dash, and space first contacts. Any one of these stamps may be impressed, by means of a suitable finger piece, on the paper, which remains fixed to receive the impression. The rise of the stamp after making the impression causes the forward motion of the paper, by means of drawing rollers moved by a ratchet wheel and pawls. The amount of rise, either directly or by the interposition of different levers for the different bosses, determines the distance to which the paper is drawn forward after each impression or boss is made, and determines the length of what has been called the second contact.

Figures 16A to 16D show an embossing key with adjustments which enable it to be used for various kinds of contacts; Figure 16A shows a side elevation; Figure 16B an end elevation; Figure 16D a plan, and Figure 16C part of the detail of the key.

A, B, C, are three finger pieces hinged on the shaft D. Each finger piece carries one die or stamp *a*, *b*, and *c*. In the Drawing the stamps are arranged to make bosses for our "first" and "second" improvements applied to Morse signals; *b* is the longest or "dash stamp"; *c* is the shortest or "space stamp;" *a* is the medium or "dot stamp." The screws *l*, *m*, *k*, in A, B, C, respectively press the levers L, M, K, whenever the corresponding finger piece is depressed. The levers L, M, K, are hinged on the shaft N, and their other

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ends are all connected to a shaft P; when, therefore, any one of the levers L, M, or K, is depressed, they all move together. When not forcibly depressed by the finger pieces, these levers are kept up in the position shown in the Drawing by a spring Q attached to shaft P, and passing through a slot in finger piece B. The shaft P carries at one end a catch S fast on the shaft and at the other end a ratchet R loose on the shaft, pressed outwards by a spring *n*; T is the drawing roller, it carries two ratchet wheels *r* and *s*, of an equal number of teeth, but put on in opposite directions. The ratchet R turns the drum by means of the wheel *r*. The catch S stops the drum when the shaft P is at a certain height by catching under the ratchet wheel *s*; *p* is a spring with a catch at the head, which prevents the roller T from going back whilst the ratchet R is descending; *t* is an ordinary friction roller, pressing the paper against the drum T; U is the block in which the impression of the stamps is made; it is most easily made of tin, the stamps making their own impression; V is a clip to hold the paper fast on the block whilst the impression is being made; it is pressed down by the bar *v* resting on the spring *w*; this bar is carried by arms on a hinge *y*, V is also hinged at *y*. A spring (not shown) lifts V when not in action. The bar *v*, and consequently clip V, are depressed by one of the three set screws *f*, *h*, or *i*, when A, B, or C, are depressed; *x*, *x*, are guides for the paper, the course of which is shown by a dotted line thus ——·——·——·. The weight of the finger pieces A, B, C, is counterbalanced by small springs at *z*. Stops (not shown, prevent too much rise in the finger pieces A, B, C.

The action of the instrument is as follows:—The paper is put in as shown by the dotted line. If a dash is wanted B is depressed; by doing this the screw *m* depresses the arm M, the shaft P, the ratchet R, and the catch S, (the spring pawl *p* keeps the roller T from moving); the screw *h* presses down the bar *v* and the clip V, and holds the paper firmly; the stamp *b* then enters the impression in the block U and makes the boss. When B is released the spring Q lifts shaft P, the ratchet R turns the drum T, taking three teeth of the wheel *r*; the paper is thus drawn forward the necessary distance, the clip V having been released by the rise of the screw *h*. When the roller T has moved forwards a sufficient distance the catch S stops it, and at the same moment the pawl *p* falls into gear. The upward motion of the piece B was caused both by the mainspring Q, (through the screw *m*,) and by the small spring at Z. The pieces A and C did not descend at the same time that B was touched, being prevented by springs at Z. The dot and space bosses are made in a similar manner by depressing A and C; when A is depressed two teeth only are taken by the ratchet R; when C is depressed one tooth only is taken. The adjust-

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ment of *k*, *l*, and *m*, in a slot on the finger pieces A, B, and C, allows this to be regulated with nicety; greater or less descent of the finger pieces, and consequently greater or less leverage over the spring Q can also be obtained by the adjustment of *k*, *l*, and *m*. With slight modification the same key can be used to impress bosses suited to any required sequence of contacts. By changing the stamps *a*, *b*, and *c*, and readjusting *k*, *l*, and *m*, bosses to suit many sorts of contacts can be made.

Our "eighth" and "ninth" improvements may be used with advantage to make the sequence of contacts required for any of the usual methods of signalling, and especially to make the sequence of contacts required to carry out the fourteenth part of William Thomson's Patent, bearing date Twentieth February One thousand eight hundred and fifty-eight, already quoted.

Figure 17 shows paper prepared by the key shown in Figure 16 to send the words "id est" in Morse signals by our "first" and "second" improvements through submarine lines. One contact tongue, such as F in Figure 15, is required.

Figure 18 shows paper prepared to send the same words by common Morse signals through short or land lines.

Figure 19 shows paper prepared to send the words "id est" in Morse signals by the same series of four contacts, as is described in our "seventh" improvement. Two contact tongues, such as F in Figure 15, are required side by side, one being actuated by the bosses A, A, the second by the bosses B, B. Thus when the tongue over A, A, is raised, and that over B, B, is down, a strong positive current is sent; when the tongue over B, B, is up, and that over A, A, is down a negative current is sent. When the tongues over A, A, and B, B, are both up, a weak positive current is sent; when both tongues are down the line is connected with earth.

Tenth, we employ instruments by which each mechanical signal (such as the depression of a stop) prints or shows a symbol or letter; for this purpose we employ a sending arm and a receiving disc or type wheel driven by friction at equal speeds. When the sending arm is arrested by a stop, the contacts between the sending battery and the line are so modified that the receiving disc or type wheel is stopped by the action of an electro-magnetic detent; when the arm is allowed to resume its motion the original contacts are re-established, and the receiving disc or type wheel being released also resumes its motion. The angular motion of the sending arm between two successive stoppages and that of the receiving disc or type wheel are consequently equal. If stops corresponding to an alphabet are ranged round the sending arm, and corresponding letters or types fixed to the receiving disc or type wheel, the angular motion

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of the sending arm, which occurs when stop "A" is released and stop "G" depressed, will allow an equal angular motion in the receiving disc or type wheel, and thus that disc or type wheel (previously set with A visible or opposite the printing roller) will be stopped with G in sight or opposite the printing roller; during the stoppage the letter is read or printed by a local circuit or by a mechanical arrangement. If the stop E is not depressed, and the stop G released at the sending station, the letter E will also be read or printed at the receiving station, and thus any succession of symbols may be transmitted.

When the instrument is required only to shew letters, not to print them, an arm attached to the receiving wheel may be used to point to letters on a fixed dial behind it. The time during which the sending arm is stopped is immaterial, provided it is stopped for sufficient time to allow of the contacts being made at the sending end, and the letter read or printed at the receiving end. A single instrument answers the purpose of transmission and reception, the sending arm being fastened to the receiving disc. When sending it is arrested by the stops, when receiving it is stopped by the electro-magnetic detent.

The mechanism used for sending these signals is shewn in Figures 20^a, 20^b, and 20^c. An upright shaft A driven at an uniform velocity carries a disc N, N, which revolves with the shaft. An arm B, B^1, is loose on the shaft A. The friction of the disc N, N, against the two ends M and C, of the arm, tends to carry the arm round at the same speed as the disc in the direction shown by the arrow; an adjusting screw at M regulates this friction. The end C of the arm is made of vulcanite or other insulating material. There are three terminals on C, viz^t., H, F, and V. H and F are simply metal stops from which insulated wires are carried along the arm close to the axis of the shaft, and are ultimately led into the fixed annular mercury troughs L and I at *h* and *f* respectively. V has a small metal spring D in connection with it. D is armed with platinum, and is used to make contact with F and H alternately. An insulated wire is led from V to dip into the fixed annular mercury trough K at *d*. These mercury troughs may be replaced by pullies insulated from one another, loose on a fixed shaft, the wires being connected to the revolving pullies. By its trough or pulley *d* is connected with the line, and *h* and *f* are connected respectively with the two sources of electricity required to make the first and second contacts for signals; for instance *f* may be connected with earth, and *h* with one pole of a battery, the other pole of which is connected with earth. A fixed ring P, P, is placed concentrically with the disc N, N. Thirty stops on this ring are lettered (zero) 0, A, B, C, D, etc. These stops have a finger piece (Figure 20^c) a hinge R, and an insulated catch *x*, which stops

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the arm B, B¹, by catching against D whenever a stop is depressed by the operator's finger. A spring S raises the stop when the finger is removed.

The action of the instrument is as follows:—When no stop is depressed the arm B, B¹, revolves at the same speed as the disc N, N, and the spring D presses against the terminal F, putting the line in connection with earth. When any stop, for instance $\overset{(zero)}{0}$ is depressed, the catch *x* shortly afterwards when the revolving arm B, B¹, comes opposite to the stop $\overset{(zero)}{0}$, catches against D and presses it against the terminal H, stopping the arm B, B¹, and sending a current through the line. The friction of N, N, against the arm B, B¹ maintains this contact so long as the stop is depressed. When the stop is released, the spring D flies back against the terminal F, and the arm B, B¹, begins to revolve at the same speed as N, N, until again arrested by the depression of a stop. The line may thus be kept in connection with earth for definite periods of time depending on the succession of stops touched.

The receiving mechanism is represented in Figure 21. A shaft B revolves at the same speed as the shaft of the sending instrument. This speed can be adjusted by one of the governors to be hereafter described. Two discs A and C are fastened together, but are loose on the shaft B unless stopped by other means; they are driven by friction at the same speed as the shaft B. The disc A has thirty small metal catches *a*, *a*, *a*, etc. These catches are all in metallic communication, but the rim of the disc between each is of insulating material, such as vulcanite. The disc C has thirty types upon its rim, *b*, *b*, *b*, *b*, etc. The discs A and C can be stopped by the catch E, moved by an electro-magnetic detent, which will hereafter be described. When the catch E stops the disc it also makes a connection through the metal catches *a*, *a*, *a*, by which a local battery acts on the electro-magnet L, L¹, depressing H and raising F, parts of an armature hinged at I. The rise of F, raises a roller or platen K, over which a strip of paper passes, and presses the paper against the type which happens to be opposite. When the catch E is withdrawn, the local circuit is broken, and K, with the paper, falls away from the type. Each movement of the end K of the armature also draws the paper forward a definite distance by a pawl and ratchet (not shown).

The combined action of the sending and receiving mechanism is as follows:—The main shafts of the two instruments being set at the same speed, the stop $\overset{(zero)}{0}$ of the sending instrument is to be depressed, and the type wheel of the receiving instrument is to be brought, with the type $\overset{(zero)}{0}$ opposite the paper roller (the type $\overset{(zero)}{0}$ prints a dot only); under these conditions the

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arm B, B¹, is stopped, a current is passing through the line, the catch E holds the discs A and C, and the roller K presses against the type (zero) 0. Now, if the words "id est" are to be sent, the sending clerk releases the stop (zero) 0, and presses the stop I; the arm B, B¹, (Figure 20) begins to revolve, the spring D (Figure 20) touches F, the current through the line ceases, the catch E (Figure 21) releases the discs C and A (Figure 21), which begin to revolve at the same speed as the sending arm B, B¹, (Figure 20), the roller K drops, and the paper is pulled on. When the sending arm B, B¹, comes opposite the depressed stop I, the arm B, B¹, is again stopped, and a current is again sent through the line, which causes the catch E (Figure 21) to stop the discs A and C, and the roller K to rise, printing a letter on the paper; this letter will be the letter I, for the sending arm and the receiving disc started simultaneously or nearly so, travelled at the same speed, and stopped at the same moment. The stop *x* (Figures 20ª and 20ᶜ) is tapered, so that the spring D is slightly delayed in its passage from H to F, in order that the current shall not be interrupted for quite so long a time as is employed by the arm in travelling from (zero) 0 to I or from I to D; by this precaution the catch E (Figure 21) is sure to fall against the rim of disc A a little before the catch *a*, corresponding to the letter to be printed, has arrived opposite E. This precaution renders extreme accuracy in the speeds of the sending and receiving instruments unnecessary, since if the catch E falls anywhere in the considerable space separating the stops *a*, *a*, corresponding to types H and I, the letter I will be printed, the local or printing circuit not being completed until E touches the catch. The letter D is next sent by releasing stop I and depressing D, keeping it down till the arm B, B¹, stops for a moment The stop (zero) 0 is next touched, which sends a space, or in other words, moves the paper, printing only a little dot, and so on.

For distinctness, the sending and receiving parts of the mechanism are shewn in different Figures; practically they would at each station be on the same shaft or inseparably connected. When used as a letter-showing instrument, the local circuit and electro-magnet are omitted. The disc C (Figure 21) has letters round it, the letter to be read is stopped opposite an opening in a fixed screen by the detent, or an arm may be used instead of the disc to point when stopped to letters arranged round the axis.

In the simplest form the sending arm B, B¹, (Figure 20,) by being connected to a disc with catches such as disc A (Figure 21) is also used as the receiving index, pointing to the letter on the surrounding stops. When this

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instrument is constructed for use on long submarine or underground lines, the stoppage of the arm causes the two contacts described in our "seventh" improvement as the first and second contacts to take place, the second contact being prolonged until the arm is released; the restored motion of the arm causes what were called the third and fourth contacts to take place, the fourth contact being prolonged until the arm is again stopped, these four contacts being required to carry out the fourteenth part of William Thomson's Patent, dated Twentieth February, One thousand eight hundred and fifty-eight. Figure 20^{d} is an isometrical projection of the sending arm, modified so as to produce these four contacts. A, B, H, F, *f*, *d*, & *h*, have the same signification as in Figures 20^{a} to 20^{c}. The end B^{1} of the arm B, B^{1}, is not used. D is an insulated arm hinged at *y*. At the outer end of the arm D is a set screw U, which presses against the revolving disc N, N, (made larger than shown in Figure 20^{a}). A projection T on the arm D carries a small tumbler hinged at *n*; another view of this tumbler is shown in Figure 20^{f}. V and W are two insulated terminals on this tumbler. A spring *p* by the projection *l* pressing on *m* keeps the tumbler always deflected to the right or left; its movement is limited by stops (not shown). Wires are taken from V and W to *v* and *w*, where they dip in mercury troughs or are fastened to loose pullies in the same manner as *f*, *d*, and *h*. D and *d* are put in connection with the line. Let the four sources of electricity be numbered according to their potentials 1, 2, 3, and 4. No. 1 may be a strong positive current; No. 2, a weak positive current; No. 3, the earth; No. 4, a negative current. *w* is connected with 1, *f* with 2, *v* with 3, and *h* with 4. A slight friction applied to the hollow shaft *b*, b^{1}, prevents it from moving unless driven by the arm B.

The action of the instrument is as follows:—When one of the letter stops (Figure 20^{a}) is depressed, the catch *x* comes against the end of the set screw U, and stops arm D, pressing it against H, where it remains. The line is thus put in connexion with earth. Neither W nor V touch D, but W is very close to D in the position shown, Figure 20^{f}. When the letter stop is released, the friction of N, N, against U carries on the arm D which first touches W, sending a strong positive current into the line; when the tumbler is vertical the arm B touches F, the tumbler at that instant falls over, leaving D in contact with F only, but bringing V close to D; the arm B hitherto kept from moving by friction on the hollow shaft *b*, b^{1}, now begins to revolve. When U is caught by another stop, D leaves F, and at once comes in contact with V, sending a negative current. This is followed by D touching H, the tumbler falling over at the same instant into the position shown in the Drawing (Figure 20^{f},) when the line is again connected with earth. The momentum of the

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arm B carries A on till stopped by the contact of D and H. The contact is maintained, or the recoil of arm B prevented by a small catch *z* projecting from B and catching the stop *x*, on the opposite side from that touched by U. This catch is so made as to pass *x*, easily but to allow no return. Thus the first contact is made for a very short but definite time depending on the speed of the disc N, N, and the motion allowed to D. The fourth contact is made for a very short but definite time depending on the velocity acquired by the arm B, and the motion allowed to D. The second and fourth contacts may be indefinitely prolonged. The distance traversed by D on arm B must be small compared with the distance separating two catches *x*, *x*, of two successive letter stops.

Eleventh, we use an electro-magnetic detent made as follows:—(Figure 21) a bar of soft iron *n*, *s*, is supported inside two galvanometric coils G, G^1, so as to be free to move back and forwards along their axis between two stops. The two coils are fixed with their axes in line; they are so connected that the current passes through them in opposite directions round their common axis. The bar of soft iron is powerfully magnetised by a large horse-shoe magnet N, S, the two poles of which are placed opposite the ends of the soft iron bar. The received current passing through the two galvanometric coils causes each to exert a force on the magnetised bar of soft iron, tending to move it in the same direction along the axis. This force is used to move the bar from one stop to the other. The cessation or reversal of the current causes the return of the bar to its original position. The strength of current in the coils by which the movement of the soft iron bar is determined from one stop to the other can be adjusted either by a spring or by a magnetic adjustment. We use the same combination of coils soft iron and magnet as a "relay" or "pecker"; the movement of the bar of soft iron under the influence of a current being used to make and break contact.

Twelfth, we regulate the motion of those parts of our mechanism which revolve at an uniform speed by a governor which applies a break. One form of governor employed is called by us the "static reaction governor." This governor is a centrifugal governor, in which the static reaction resisting the centrifugal force developed in the revolving mass is employed to apply a break to the revolving shaft of which the motion is to be controlled, whilst at the same time this application of the reaction is so contrived as not to affect the divergence of the revolving mass from the axial shaft. We employ two forms of this governor. In the first form the axial revolving shaft is vertical, and a single ball or mass of any convenient shape carried by an arm hinged on the axial shaft is employed. The axial shaft is in the prolongation of the driving

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shaft, but is hinged on this shaft so as to be free to deflect from its vertical position. This deflection is restrained within a very small limit by an horizontal arm projecting from the axial shaft, the other end of which presses against a fixed surface of revolution and produces the required friction. The divergence of the ball or mass from the axis of the shaft is not affected by the use made of the tension of the arm to apply the break. Figure 22 shows this form of governor; C, is the driving shaft, A, B, is the axial shaft hinged at B; B, G, is the horizontal arm pressing against the fixed surface F F. The divergence of the ball or mass D from the axial shaft increases the friction between G and F, and so controls the speed of the axial shaft.

In the second form of governor a spring is substituted for the action of gravity, to restrain the centrifugal force of the revolving mass or masses. The static reaction of this spring sliding on a fixed surface, which is either a plane surface perpendicular to the shaft, or a coaxial surface of revolution, produces the required friction. The spring is so adjusted as to exert a force in simple proportion to the angle of displacement for small displacements, and there is no great deviation from this law throughout the entire range of displacement. The divergence of the rotating mass from the axial shaft is not affected by the employment of the reaction of the spring to produce friction, or, in other words, to apply the break.

Figure 23 shews one arrangement this form of governor. A, B, is the axial shaft, of which the speed is to be controlled; D and D^1 form the rotating mass; D and D^1 are carried by arms hinged at C. The spring F restrains the divergence of D and D^1 from the axial shaft; K, I, is the plane surface perpendicular to the shaft A, B; L is a set screw forming the stop, which limits the approach of the masses D, D^1, to the axis A, B; M is a stop, which limits the divergence of the masses D, D^1, from the axis. The divergence of the masses D, D^1, increases the pressure of the spring F against K, L, at H. The friction of H against K, I, controls the speed of the shaft A, B. In both forms the movement of the mass is limited by stops, which permit it to move from a point very near that of unstable equilibrium (so far as centrifugal force is concerned), through an acute angle towards the position of stable equilibrium (so far as centrifugal force is concerned). Until the required speed is attained, the mass presses towards the axial shaft against the inner stop, but when the required speed is passed, even by a very small quantity, the mass diverges considerably from the axis, and by the above arrangements can be made to exert a large break power.

Thirteenth, another governor used by us is called the spring and pallet governor. We use the usual form of single or double ball governor so far as

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the general features of the revolving system are concerned; a catch projects from one or both balls outward from the central shaft. When the divergence of the ball or balls exceeds a certain limit this catch comes in contact with a series of fixed springs arranged in a circle round the axis of the governor. These springs are so fixed and shaped that by a small displacement of the end struck the catch and ball are allowed to pass. The surface of contact of the spring and catch must form nearly the limiting angle of friction with the normal to the circular line of motion of the catch, in order that no force may be exerted by the springs, either to press the catch towards the axis, or to retain it at a distance from the axis. The retarding force is that which is exerted by the springs to prevent the passage of the ball and catch. This form of governor is shown in Figure 24. A, B, is the axial shaft; C, the mass, carried by an arm hinged at A; D is the catch; and F, F^1, F^{11}, etc., the springs arranged in a circle round the axial shaft. This form may be varied by placing a spring on the ball and catches in a circle round the axis of the governor.

Fourteenth, we also use a chronometric governor where great accuracy is required. In this governor break power used to prevent the mechanism from passing a certain speed is increased or diminished respectively during any deviation of a mass from the axis round which it rotates greater or less than one constant deviation. So long as the speed required is accurately kept the mass revolves unimpeded at a constant distance from the axis, and the retarding force is unaltered. Any increase of speed, by increasing the distance of the mass from the axis, brings the mass into contact with a catch or tooth on a wheel, which, being turned by the mass as it revolves, increases the break power until the speed is reduced to that required; any diminution of speed by diminishing the distance of the mass from its axis brings the mass into contact with a catch or tooth on a second wheel, which, being turned by the mass as it revolves, diminishes the break power until the speed is increased to that required. The friction caused by the pressure of part of the mass against a smooth surface on the first and second wheels will, in some cases, be sufficient to turn those wheels; in those cases the catches or teeth may be omitted.

One arrangement of this form of governor is represented in Figure 25. A, B, is the axial shaft, of which the speed is to be controlled; C is the revolving mass, hung on an arm hinged at A; D is a catch on the mass C; F, F^1, is a toothed wheel loose on the shaft A, B, connected, by means of a hollow shaft, with the toothed wheel H, H^1; E, E^1, is a wheel with internal teeth concentric with the wheel F, F^1; it is loose on the shaft of F, F^1, and

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connected by a hollow shaft with an internal toothed wheel G, G^1. A pinion I, carried by a shaft K, gears with the two wheels G, G^1, and H, H^1; when turned in one direction, the shaft K increases the friction of a break connected with the shaft A, B; when turned in the opposite direction it diminishes the friction of the break (not shown). The action of the governor is as follows:—So long as the speed of A, B, is that required, the catch D revolves between the two wheels F, F^1, and E, E^1, touching neither. These two wheels do not then turn round, being held by the resistance of the shaft K. If the required speed is exceeded, the mass C diverges further from the shaft A, B, the catch D gears with a tooth of the wheel E, and turns it round in the direction in which the shaft A, B, revolves. By means of the wheel G, G^1, and the pinion I, the shaft K is also turned, and the break power increased until the speed of the driving shaft is reduced to that required, when the catch D again revolves freely between F, F^1, and E, E^1, and the toothed wheels all stand still, the break which had been applied remaining unaltered. Similarly, if the speed of the driving shaft falls below that required, the catch D gears with a tooth of the wheel F, F^1, which, by means of the wheel H, H^1, and the pinion I, turns the shaft K in an opposite direction, and diminishes the break power applied. The static reaction governor may be combined with this form by letting the static reaction of the ball apply friction within certain deviations, but beyond these deviations letting a catch gear with wheels, as in the form just described. The surfaces of the catch D, and the teeth of the wheels E, E^1, and F, F^1, should be at the limiting angle of fraction, so that the pressure between them shall exert no force either to retain the catch in contact, or to force it from contact with the teeth.

In the arrangement just described, centrifugal force repels the mass from the axis, and a component of the force of gravitation draws it back. This form may be modified by substituting the resistance of the air for the centrifugal force of a weight, and the force of a spring for that of gravitation. The ball is then replaced by a flat vane at such an angle with the plane passing through the axis and hinged arm that the resistance of the air tends to float the vane outward. This angle can be adjusted. The outward movement is restrained by a light spring. The small weight and inertia of the moving parts gives this form some advantages.

Fifteenth, it is of great importance that there should be little variation in the electro-motive force or resistance of the batteries employed; we therefore use Daniell's constant batteries of the following forms. When porous diaphragms are employed to separate the two liquids we connect the

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two liquids by means of a syphon, and thus prevent any change of relative level in the surface of the two liquids.

Sixteenth, we also use a portable Daniell's battery without porous cells. A trough or saucer is made of insulating material. A piece of copper or other positive metal is bolted to the bottom by a bolt passing through the bottom of the trough or saucer. The opening is made water-tight by the use of an elastic washer under the head of the bolt. Powdered crystals of sulphate of copper are strewn on the plate; a layer of sawdust is next placed in the saucer moistened with sulphuric acid and water; on the top of the sawdust, nearly level with the top of the saucer, a zinc plate is laid. Several of these saucers having been thus prepared they are laid one on the top of the other. The bolts passing through the bottom of each saucer form, directly or indirectly, the connection required between each cell. The saucers are then firmly secured together by bolts passing through lugs on the saucers, or by other suitable means. A battery of three pairs of plates constructed in this manner is shown in Figure 26. A, A^1, A^{11}, are three insulating saucers, fitted one on the top of the other, with a small gutter round the top of each; Z, Z^1, Z^{11}, are three zinc plates resting on the top of sawdust; C, C^1, C^{11}, are three copper plates bolted to the bottom of the saucers by copper bolts *b*, *c*, *d*. These bolts are made water-tight by elastic washers under their heads. A bolt *a* through the insulating lid H is connected with one terminal wire P; the other terminal wire P^1 is connected with *d*. B and D are two bolts connecting all the saucers together, and pressing the bolts *b*, *c*, *d*, against the zinc plates, thus ensuring a good contact. The gutters receive any superfluous moisture pressed out of the sawdust, and allow the batteries to be refreshed occasionally by the addition of a little acid and water.

Seventeenth, we use an instrument which we call a "divider." By this instrument a difference of potentials is produced in two terminals equal to any definite part of the difference of potentials resulting from one or more cells, and thus currents of various definite strengths are produced in any arc joining the two terminals. We use this instrument to subdivide electro-motive force in working our "seventh" improvement, in balancing earth currents, and in many other combinations.

The instrument is constructed as follows:—The two poles of the cell or battery are connected through a reversing key with a series of "n" equal resistance coils; the end of each coil is connected with the beginning of the next at a brass terminal. There are thus "$n+1$" terminals. These terminals are arranged in a row, and numbered (zero) 0, 1, 2, 3, ... n. A stout brass

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bar is fixed parallel to the row of terminals, and a spring slides on the bar, so that it can readily be brought by hand to press on any one of the terminals; when the spring is at terminal (zero) 0 that terminal and the bar are simply put in short metallic communication, so as to be maintained at the same potential. When the sliding piece is drawn along the bar so as to make the spring press on any other terminal, No. 1, for instance, the bar and the terminal (zero) 0, if kept perfectly insulated from earth, and also from one another, except through the spring and resistance coil, are maintained at a difference of potential amounting to the fraction $\frac{1}{n}$ of the whole difference of potential maintained by the battery at the extreme terminals (zero) 0 and "$n+1$." By the use of the reversing key this difference of potentials may be reversed. If the bar and the terminal (zero) 0 are now joined by an arc, of which the resistance is great compared with that of the resistance coils, the difference of potentials in the bar and the terminal (zero) 0 will still be that called $\frac{1}{n}$, and a current will flow through the arc; if this current be called "a," then the current flowing through the arc, when the spring is at terminal 2, will be $2a$, the difference of potentials in the bar and the terminal (zero) 0 being then $\frac{2}{n}$, and generally when the spring is at terminal m, a current will flow through the arc equal to "m, a," the difference of potentials in the bar and the terminal (zero) 0 being then equal to $\frac{m}{n}$. When the additional arc joining the bar and the terminal (zero) 0 is of small resistance compared with that of the resistance coils, the relation of the various currents produced in the arc when the spring is at different terminals is no longer so simple; but these currents may be calculated, if desired, according to established principles from the resistance of the battery and of the several arcs dealt with.

Figure 27 is a diagram representing the connections of the divider 0 (zero) is an insulated terminal connected with one pole of the battery N; the other pole of the battery P is connected to terminal No. 25. The two poles of the battery are thus connected through the 25 equal resistance coils a, a, a, etc. B, C, is the insulated brass bar on which the slide A moves back and forwards, so that its spring may be in contact with every one of the terminals 1, 2, 3, 4, etc. One end of the additional arc F, through which it is wished to send currents of various strengths is connected with the bar B, C, and the other end is connected with the terminal (zero) 0. Then, if this additional arc F is of

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great resistance compared with that of the 25 resistance coils the current which flows through the arc F when the spring A presses on terminal 25 will be 25 times greater than that flowing through the arc when the spring A is pressing on terminal 1.

In witness whereof, we, the said William Thomson and Fleeming Jenkin, have hereunto respectively set our hands and seals, this Twenty-third day of February, in the year of our Lord One thousand eight hundred and sixty-one.

WILLIAM THOMSON. (L.S.)
FLEEMING JENKIN. (L.S.)

LONDON:
Printed by GEORGE EDWARD EYRE and WILLIAM SPOTTISWOODE,
Printers to the Queen's most Excellent Majesty. 1861.

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FIG. 1.

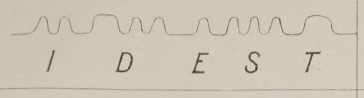


FIG. 2.

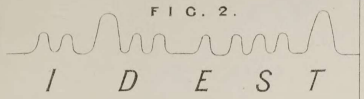


FIG. 3.

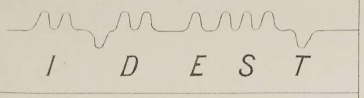


FIG. 4.

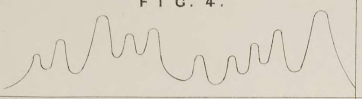


FIG. 5.

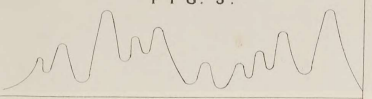


FIG. 6.

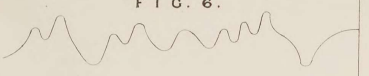


FIG. 7.

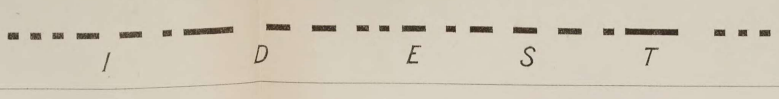


FIG. 8.

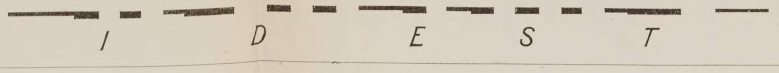


FIG. 9.

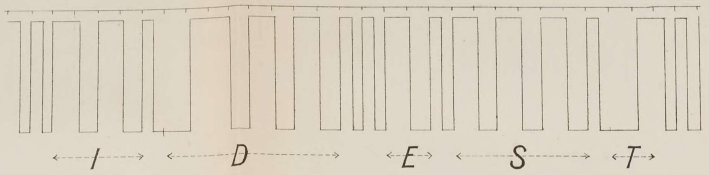
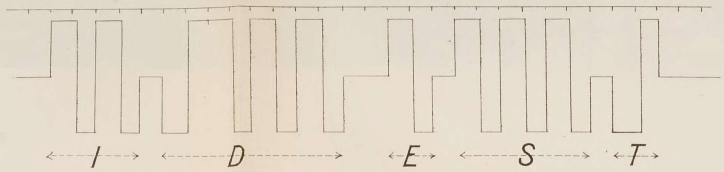


FIG. 10.



Elevation

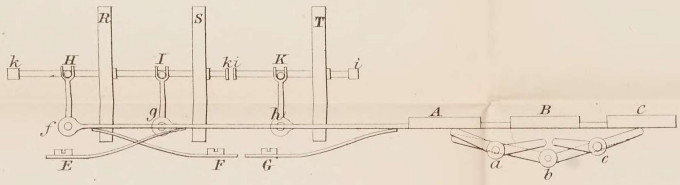
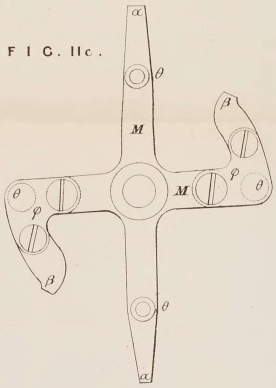


FIG. IIc.



End Elevation

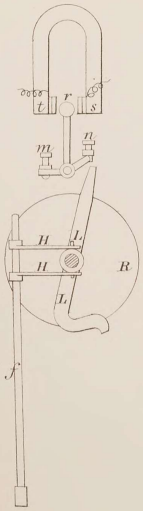
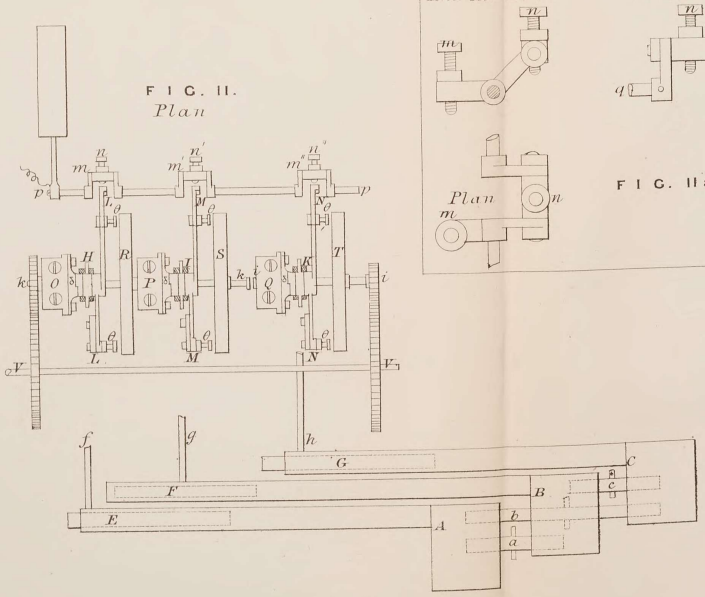
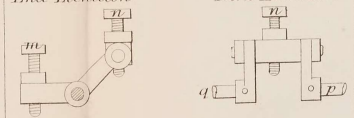


FIG. II.
Plan



End Elevation *Front Elevation*



Plan

FIG. IIa

FIG. IIb.

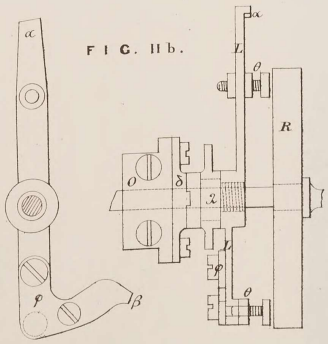
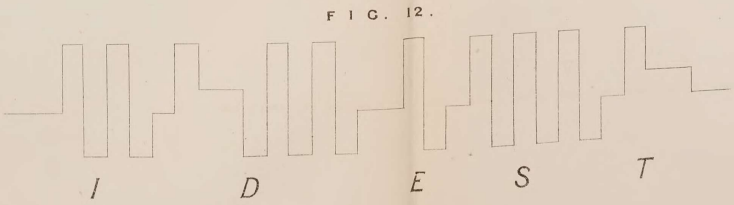


FIG. 12.



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Printers to the Queen's most Excellent Majesty. 1861.

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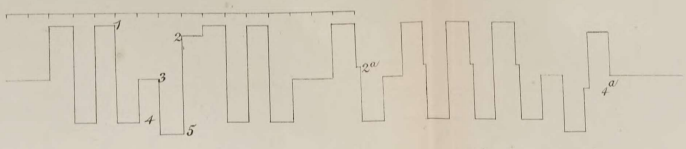
FIG. 13



I D E S T

FIG. 14b

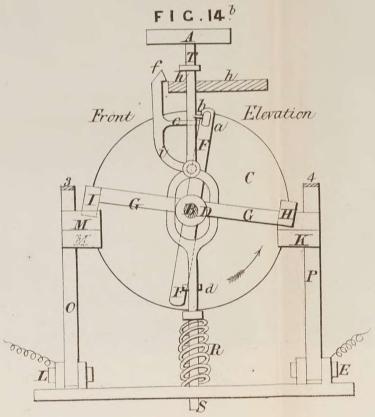


FIG. 14c

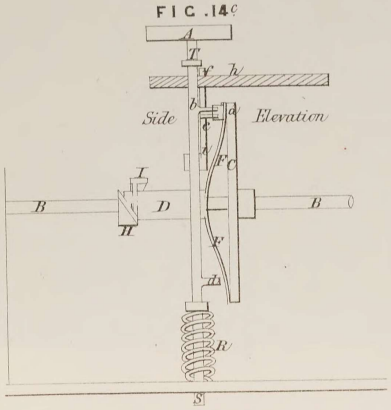


FIG. 14e

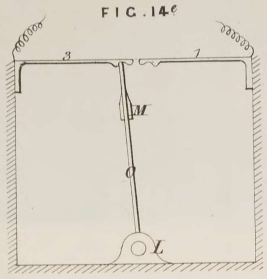


FIG. 14d

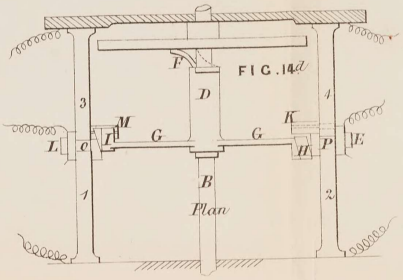


FIG. 14f

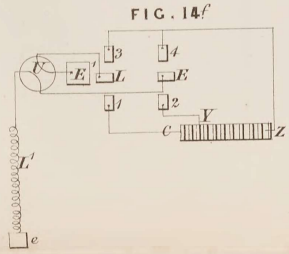


FIG. 14a

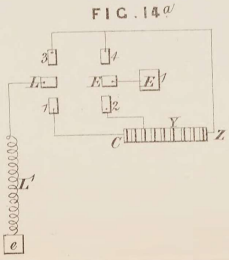


FIG. 16A

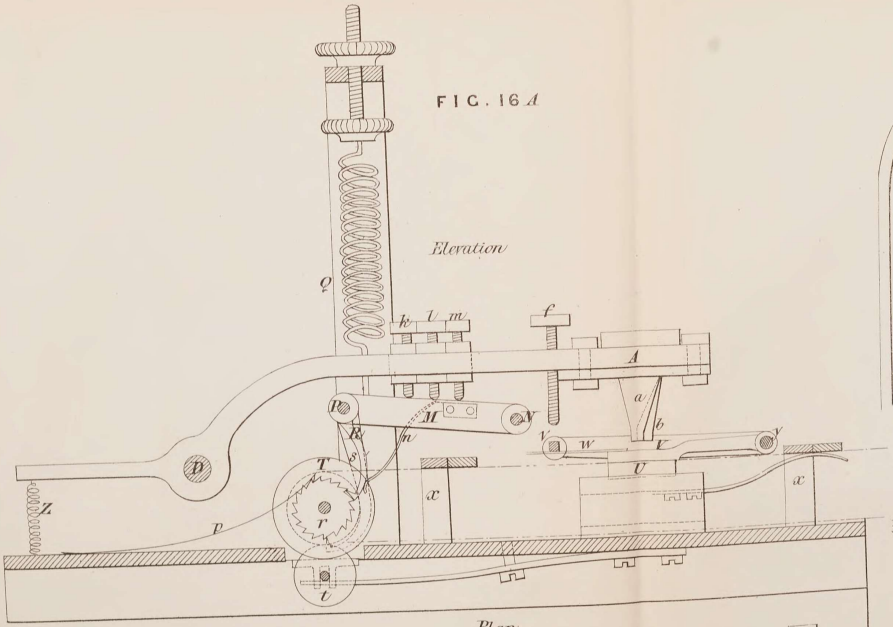


FIG. 16B

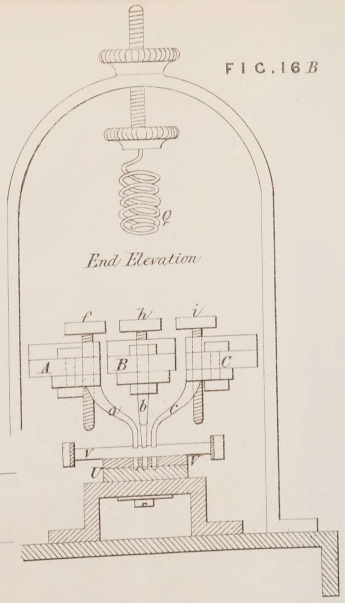


FIG. 16C

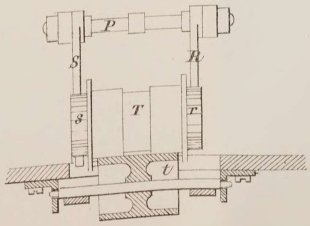


FIG. 16D

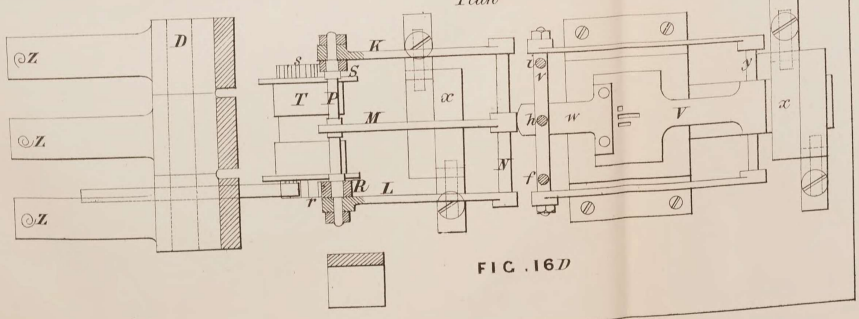


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FIG. 15.

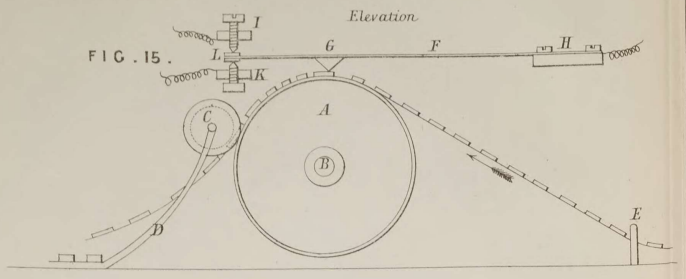
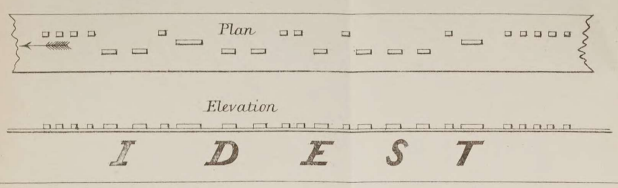


FIG. 17.



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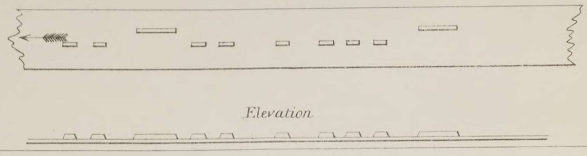

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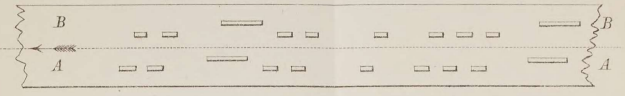

FIG. 20b

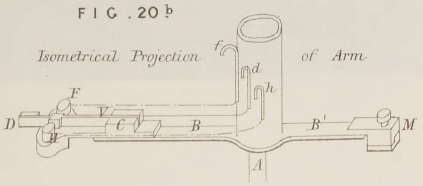

FIG. 20a

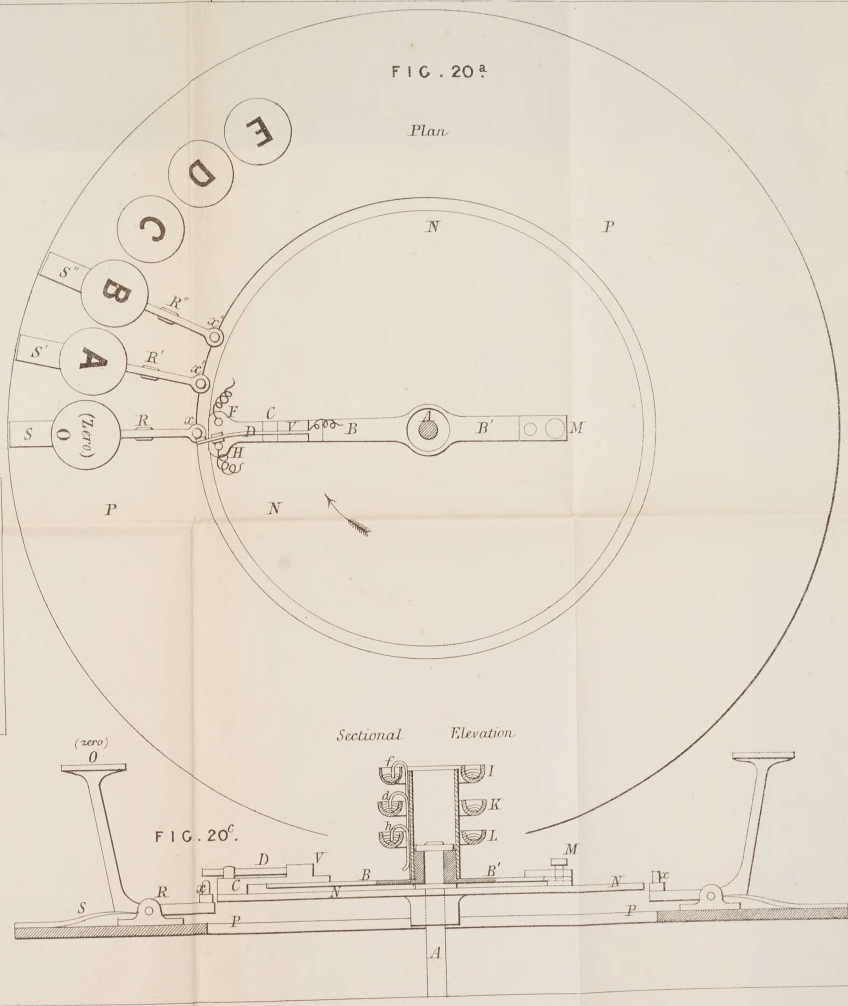

FIG. 20f

FIG. 20d

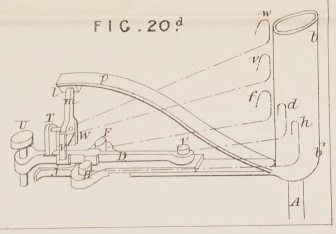

FIG. 20c.

FIG. 21.

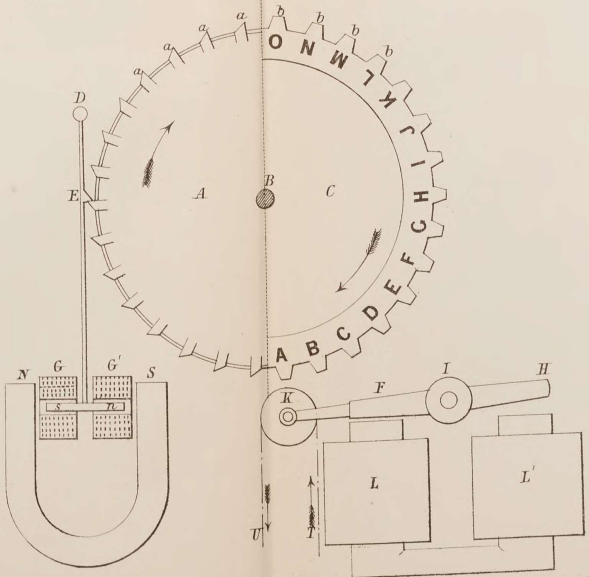

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FIG. 22.

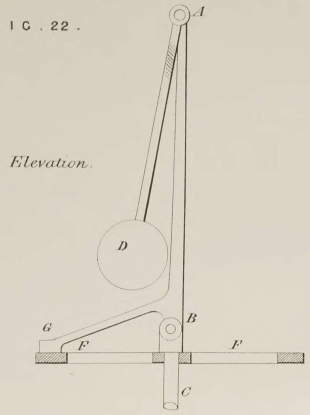


FIG. 24.

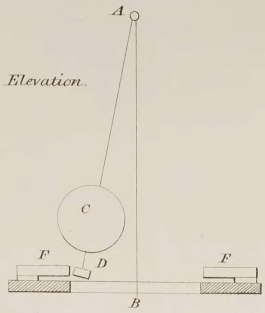
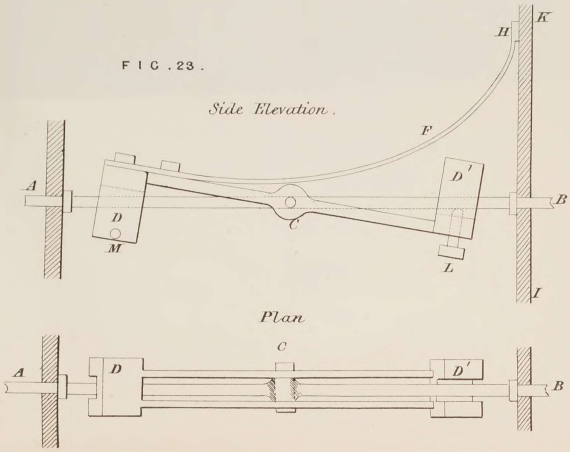


FIG. 23.



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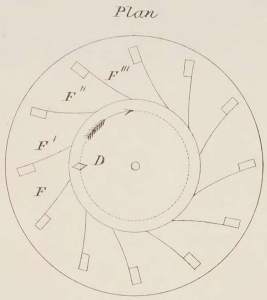

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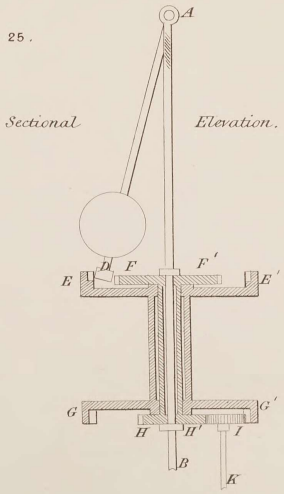
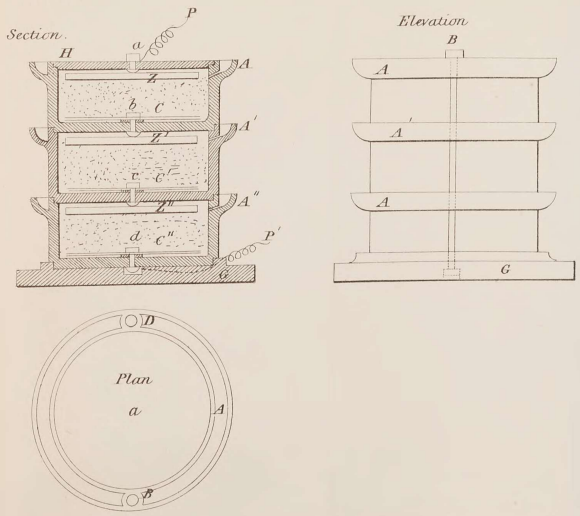


FIG. 26.



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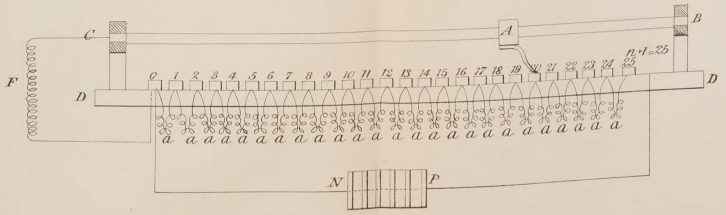

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